Choosing an op amp can be as frustrating as shopping for new wallpaper. You have to peruse multiple data books and parts—much like the dozens of design books at the store, each with hundreds of wallpaper patterns. It's easy to feel overwhelmed and hard to feel confident you've made the *right* choice. Yet, you can be sure that, with a little bit of perseverance, you'll find the *best* selection. To complicate the process, because there are so many parameters that define an op amp, someone will probably challenge your selection by using a different set of priorities.

But don't worry. Even though vendors have introduced dozens of op amps in the past few years, the good news is that many of these devices are far superior to their predecessors. Newer op amps not only reduce the number of frustrating trade-offs among speed, power, cost, accuracy, and size, but also carry more complete specifications.

Best of all, many of these new op amps are application-specific, providing special features unique to an application, along with data sheets that offer relevant specs, characterizations, and how-to-use circuits. You can select a part by its desired function and intended application (for example, driving a 75Ω cable) rather than by looking at an underlying op-amp process technology (FET vs bipolar input or bipolar vs CMOS vs mixed-process fabrication) or a dominant spec, such as output current drive.

By far the largest number of recent op-amp introductions suits low-power, single-supply applications. Note that, although "low power" and "single supply" are technically independent parameters, they are often inseparable needs. A few years ago, op amps were associated with ±15V supplies, which shrank to ±5V then to just +5V; now, nominal +3V supplies (and even lower) are common—with surprisingly little sacrifice in device performance. Wireless applications, such as personal communicators, keyless data entry, RF identification, and handheld test-and-measurement equipment, have driven this supply-rail reduction.

Yet, you should take time to consider operating conditions when applying such low-power, low-voltage devices. They are not as forgiving of system-design shortcomings because they have less input range to accommodate poorly behaved input signals, less head room to defeat unfavorable S/N ratios, and less reserve capacity to overcome output-drive problems.

According to most vendors, common-mode voltage is an area of confusion for designers. The op amp must accommodate your ac signal in addition to a dc signal that may be as large as (or larger than) its supply rail. Although early single-supply devices had common-mode weaknesses, newer devices, such as Texas Instruments' TLV2322 series, can accept an input common-mode range than goes as low as the negative rail and up to within 1V of the positive rail.

The speed-power product has also improved greatly. For example, Elantec's EL2186 and Analog Devices' AD8011 have bandwidths of 250 to 300 MHz (gain of +1) with just a few milliamps of supply current (1 mA for the AD8011, 3 mA for the EL2186) from a ±5V supply. This current consumption represents about a factor-of-100 reduction over the last 10 years.

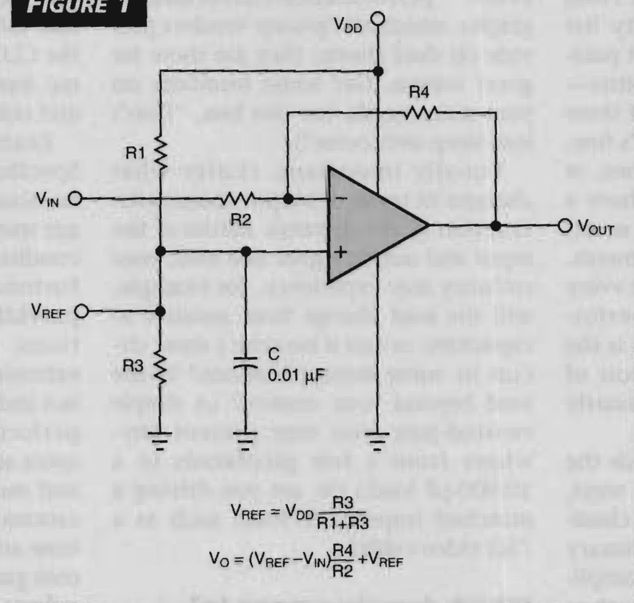
Be wary, however, for there is a trade-off when you focus excessively on low-current operation; even a few extra milliamps from the supply can make a big difference in device performance. Low-current op amps may sacrifice linearity at higher frequencies (despite internal booster circuits) and be "well-behaved" only with resistive loads. Even the capacitance of a scope probe may make the op amp oscillate or peak. Predictable and repeatable performance among units and in production is a factor to consider.

If it ain't got swing

Vendors have developed devices that, like a good race horse, can run fast and close to the rail without stumbling ("close to the rail" is a relative term, of course). Each vendor defines "rail to rail" differently, along with the test conditions. Typically, a rail-to-rail op-amp output can go as close as 100 mV of the supply rail while driving a 1-kΩ load and within 50 mV (or less) of the rail with a lighter load of 10 or 100 kΩ. Note that the supply-span-to-closeness-to-rail ratio is comparable to the one you achieve with a bipolar 15V supply (with its typical swing to within ½V of the negative rail) and within 0.6 to 1.5V of the positive rail.

This rail-to-rail capability doesn't mean that you can stop worrying about the load, though. Not all rail-to-rail devices can maintain performance at full bandwidth. Yet, you need the bandwidth to maintain low distortion and high linearity. When your load is grounded, the op amp has a much easier drive task, because it is pulling the load's high side to ground. When the load is not grounded, the

FIGURE 1



For bipolar signals, establish a reference level above ground. Although it's easy to do with a simple resistive divider, remember to take op-amp input bias current into account. Lower bias currents also let you use larger value resistors in the divider, thereby reducing power consumption.

op amp must source and sink current, which may require use of internal charge pumps, thus adding to noise and power problems. Some single-supply op amps are not designed both to source and sink current and, when used with split supplies, may have some crossover distortion as the output signal passes through the midsupply value.

Don't forget the op-amp input, either—a rail-to-rail output does not automatically ensure a corresponding input span. Further, many single-supply applications require that you apply a voltage to one input to set an above-ground reference level (**Fig 1**). This reference-setting circuit consumes less power if the op amp has low input bias current, because you can use larger value resistors in a simple voltage divider.

Stop, think, weigh

You have to begin somewhere when picking an op amp, and, luckily, you have several good strategies from which to choose. One approach is to carefully describe what the input signal looks like, that is, voltage, current, dynamics, ability to source current, etc; what the output should look like (similar criteria); and under what conditions. From this, you can develop a priority list comprising a few most important parameters as well as a few lesser priorities—with desired numbers on each. If there are one or two critical specs, that's fine.

However, if you have three, four, or more critical specs, then you'll have a difficult time finding a part that meets what may be conflicting requirements. The key here is to realize that not every application requires stellar performance; rather, the right op amp is the one with the right combination of specs—none of which is necessarily outstanding on its own.

Fortunately, vendors have made the selection process easier in two ways. Increasingly, manufacturers are classifying op amps in terms of primary application, such as photodiode amplifier, rather than dominant spec, such as low input bias current. Even better, vendors are providing detailed selection trees and guides that begin with the primary application and branch into secondary device characteristics. If you've carefully worked out your needs, these trees will lead you to a half-dozen or so suitable op-amp candidates.

You should understand the specifications of the input signal, its driving circuitry, the output signal, and its expected load (highly reactive loads can cause problems if the op amp is not designed to be well-behaved with these load types). Take time to study the relevant performance-characteristic graphs, which all op-amp vendors provide on data sheets; they are there for good reason. Get some numbers on your noise needs, too (see **box**, "Don't lose sleep over noise").

Equally important, clarify what changes in input or output characteristics, that is, the dynamic nature of the input and output signal and load, your circuitry may experience. For example, will the load change from resistive to capacitive, or can it become a short circuit in some misapplications? Is the load beyond your control? (A simple twisted-pair wire may present anywhere from a few picofarads to a 10,000-pF load.) Or, are you driving a matched impedance load, such as a 75Ω video cable?

Which domain are you in?

Another perspective is to look at op amps from your signal-processing perspective. If you're operating in the time domain, where your circuit must settle to a level when driven by a fast-changing step, your concerns are most likely step response, slew rate, and settling time. Alternatively, if you're in the frequency domain, where your circuit is following a carrier, your needs are defined by bandwidth, distortion, and load driving.

For example, Comlinear provides two "fast" op amps, each characterized quite differently. The CLC402 specs provide settling time, offset, gain range, and differential gain and phase error; the CLC409 specs encompass small signal bandwidth, harmonic distortion, and output current.

Examine data-sheet test conditions. Specifications that look adequate at nominal temperature and supply voltage may not be attainable at operating conditions that deviate from nominal. Fortunately, many vendors are now providing more thorough specifications, including performance at extremes. Typical specs, of course, do not indicate maximum and minimum performance you'll encounter. DC specs are usually available with typical and maximum (or minimum) qualifications, and ac specs such as settling time and noise are often typical values (not guaranteed by test). This situation reflects practical difficulties the vendor has in testing on a high-speed, mass-production basis; however, with some devices, such as Linear Technology Corp's LT1122, all units are tested for settling time.

DON'T LOSE SLEEP OVER NOISE

In the past, op-amp noise was a major concern for designers, and it still is in applications such as front ends for extremely low-level signals. However, process improvements have yielded devices with internal noise that is insignificant compared with other system noise sources. Today's typical noise voltages of 2 to 4 $nV/\sqrt{Hz}$ (and noise currents of 2 to 4 $nA/\sqrt{Hz}$) are comparable to the better low-noise devices from just a few years ago. Better control of the fabrication process has also reduced popcorn noise.

This doesn't mean that designers don't worry about noise (**Ref 1**). Even though the ambient digital noise is often far greater than any op-amp noise, it's an emotional, peace-of-mind issue. When you design a low-noise op amp into an application, it's one less thing to worry about, especially since you can't segregate system noise from op-amp noise. Also, although op-amp noise may be lower per root-Hertz, signal bandwidths are now greater in many applications, so the resulting total noise power may still be large. Finally, it's very difficult to compensate for noise-related errors without complex signal-processing algorithms, unlike conventional circuit errors, which you can calibrate out to a large extent.

OP AMPS

Once you have a clear understanding of what you are trying to accomplish and what performance you need to achieve this, you have two nonexclusive choices: Study the data sheets more carefully or call for help. Vendors know that good customer support is a necessity for op amps, particularly with the bewildering array of op-amp possibilities as well as application subtleties. Therefore, once you've narrowed your choice of vendors and specific models (or families), make those calls to the vendors' applications engineers (the same people who have put all those circuits and application hints on the data sheet). You should also ask for samples. But, don't mislead yourself by thinking you'll have both time and opportunity to evaluate dozens of op amps. Instead, concentrate on the few parts that are promising candidates.

Cost is often the top priority in applications. As with nearly all ICs, the cost of op amps has decreased—including higher-performance devices, too. As usual, you'll look for the least expensive part to meet your needs. But, keep your eye on the big picture. Sometimes, a slightly more expensive part with lower quiescent current decreases system costs by allowing you to use less efficient parts elsewhere, or it provides you with an extra margin of performance certainty and insurance.

LOOKING AHEAD

The driving forces for op-amp improvements continue to be lower power (with single supply), smaller size, and tailored functionality. Video, communications (wired, wireless, and fiber), and PC applications are demanding specific combinations of performance attributes—and at very low prices. You'll also see enhancement in output drive and robustness to handle real-world loads. Although accuracy and precision will improve, they are already sufficient for the majority of applications.

Vendors are now providing op amps targeted at specific applications, such as video, communications, and optoelectronics. This move is nothing new, however; some op amps have always been better suited for certain applications than others (see **box**, "Oldies but (still) goodies"). The difference now is that there are many more such parts, and they're classified by application rather than specs. Fortunately, the industry hasn't started to use acronyms for application-specific or application-optimized op amps!

In addition, vendors have modified packaging and functionality to meet the unique needs of well-defined applications. Video-application requirements, in particular, are driving many newer op-amp designs, and these parts come with comprehensive video-relevant specs, such as differential gain error, differential phase error, and gain flatness to a 0.1-dB drop-off bandwidth (rather than the traditional −3-dB bandwidth point).

Consider the common task of driving a video monitor with the three RGB signals. In this situation, a three-channel IC (rather than a dual or quad one) makes most sense. To minimize layout-routing contortions, parts such as the Maxim MAX463 series have inputs on one side of the package and outputs on the other. This design contrasts with a package having multiple channels used independently, where input and output pins are arranged alternately around the package (**Fig 2**).

The uniqueness of some video signals leads to other application-specific designs as well. To drive A/D converters, the Harris HFA1103 functions as a "sync stripper" by removing the sync signal from the component video sig-

OLDIES BUT (STILL) GOODIES

The outpouring of higher performance and specialized op amps in the last few years means that you should normally consider newest devices first for cost-effective, highest performance results. Yet, despite these new parts, a few older ones are still quite popular (excluding the generic 741 and its immediate variants). Although newer, superior parts are available, some older devices have many successful design-ins and, thus, are inexpensive, exhaustively characterized, appear on your approved-vendor list, and are often second- or multiple-sourced (comparable to the ubiquitous 2N2222 transistor).

Equally important, the older parts' idiosyncracies are well-known to vendor application engineers, which is a major advantage when doing an analog-signal-processing circuit design. Remember that the *best* op amp for your design is the one that has the right, hard-to-define combination of specs, rather than simply excelling in one dimension. Ever-popular op amps (older than six years) include

- the AD847 (from Analog Devices), a 50-MHz op amp with 300-V/μsec slew rate and video specifications
- the LT1007 and LT1037 (from Linear Technology), low-noise (4.5-nV/$\sqrt{\text{Hz}}$ to 10-Hz), high-speed (60-MHz) precision op amps for low-level instrumentation signals (with most critical specs guaranteed)
- the LTC1052 (from Linear Technology), a chopper-stabilized op amp for instrumentation with 30-pA input current and extremely low drift of 100 nV/$\sqrt{\text{month}}$
- the LM324 (from Motorola), a moderately low-power device that operates from single or bipolar supplies, with a supply differential range of 3 to 36V
- the LM6361 (from National), a wideband (50-MHz), 300-V/μsec single-supply op amp, which settles to 0.1% in 120 nsec
- the TLC27xx series (from Texas Instruments), featuring low drift (0.1 μV/month), allowing you to select a trade-off in power dissipation vs dynamic specs, from 3.4 mW down to 50 μW
- the TL06x series (Texas Instruments), a low-power (200-μA/amplifier), low-input bias current (30 pA typ) family that also has TL07x low-noise versions (18 nV/$\sqrt{\text{Hz}}$ at 1 kHz).

TABLE 1—SELECTED OP AMPS (ALL SPECS TYP)

Vendor	Device	Channels	Small-signal bandwidth (MHz)	Slew rate (V/µsec)	Input offset (mV)	No-load supply current (mA/channel)	Supply range (V)	Price (1000)
Analog Devices Inc Circle No. 301	AD813	3	125	500	2	5.5	+3 to ±15	$3.74
	AD8036	1	350	1600	2	17	±3 to ±5	$4.12
	AD8011	1	300	2000	2	1	5 to ±5	$1.95
	OP279	2	5	3	3	3	4.5 to 12	$1.31
Burr-Brown Corp Circle No. 302	OPA129P	1	0.5	0.5	0.15	1.8	±5 to ±15	$2.70
	OPA544T	1 2 (OPA2544T 2A/channel)	1.4	8	5	15	±10 to ±35	$6.00
	OPA642P	1	450	380	1	29	±5	$5.45
	OPA658U	1 2 (OPA2658T) 4 (OPA4658T)	900	1700	4.5	5.75	±5	$1.95
Comlinear Corp Circle No. 303	CLC407	1	110	650	1	3.5	±5	$1.59
	CLC425	1	1700	350	0.1	5 to 15	±5	$3.95
	CLC428	2	160	500	1	11	±2.5 to ±5; 5 to 12	$5.49
	CLC449	1	1200	2500	3	12.6	±5 or +10	$4.20
Elantec Inc Circle No. 304	EL2166C	1	110	1500	2	7.5	±3 to ±15	$2.90
	EL2176C	1 2 (EL2276C)	70	800	2.5	1	±1.5 to ±5	$1.99
	EL2186C	1 2 (EL2286C)	250	1200	2.5	3	±1.5 to ±5	$2.49
	EL4430C	1	80	380	2	13.5	±1.5 to ±15	$3.00
Harris Semiconductor Corp Circle No. 305	HFA1103	1	180	1300	6	11	5	$3.25
	HFA1113	1	850	2400	8	21	5	$5.50
	HFA1114	1	850	2400	8	21	5	$5.50
	HFA1412	4	350	1100	2	6	5	$7.41
Linear Technology Corp Circle No. 306	LT1206	1	50	600	15	5 to 20	±5 to ±15	$3.30
	LT1259	2 3 (LT1260)	130	900	10	5	±5 to ±15	$3.95
	LT1366	2	0.4	0.13	0.15	0.375	1.8 to 36	$3.46
Maxim Integrated Products Circle No. 307	MAX473	1 2 (MAX474) 4 (MAX475)	10	15	0.7	2	3 to 5	$1.45
	MAX492	1 2 (MAX495) 4 (MAX496)	0.5	0.2	0.2	0.15	±1.35 to ±3; 2.7 to 6	$2.25
	MAX472	1	N/A	N/A	0.06	0.1	3 to 36	$2.05
Motorola Semiconductor Corp Circle No. 308	MC33201	1 2 (MC33202) 4 (MC33204)	2.2	1	6	0.9	±0.9 to ±6; 1.8 to 12	$0.76
	MC33102	2	4.6	1.7	0.15	0.75	±2.5 to ±15	$1.20
	MC33304	4	2.2	0.7	3	500	1.8 to 12	$1.60
National Semiconductor Corp Circle No. 309	LM6142	2 4 (LM6144)	17	5 to 50	0.3	0.65	2.7 to 24	$2.10
	LM6361	1	50	300	5	6.8	5 to 30	$1.75
	LMC7101	1	1		4	0.5	2.7 to 15	$0.75
	LMC6462	2	0.05		0.5	0.02	3 to 15	$1.85
Texas Instruments Inc Circle No. 310	TLE2662	2	1.8	3.4	2	0.56	3.5 to 15	$1.95
	TLE2682	2	10	40	0.9	1.5	3.5 to 15	$1.96
	TLE2301	1	8	12	0.3	2.2	±15	$3.64
	TLV2362	2	7	2.5	1	1.4	±1 to ±3	$0.63

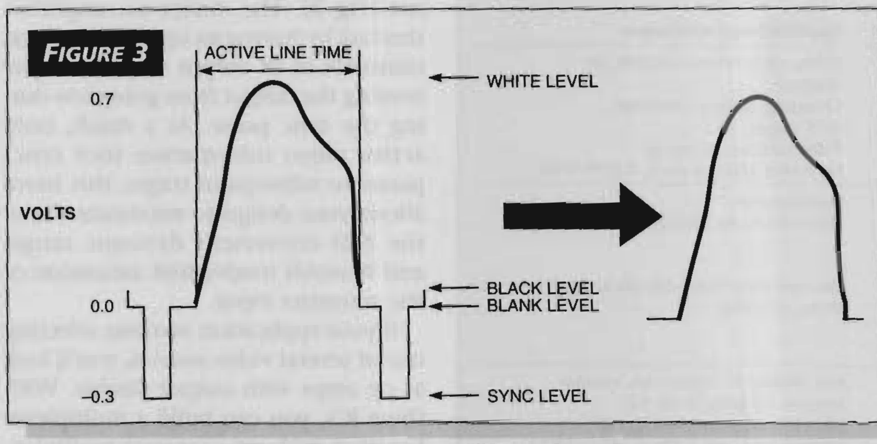
Note: N/A=Not applicable.

data-sheet curves carefully.

In video or communications applications, your input signal is often not "well-behaved" and may overrange or suffer sudden noise bursts. This out-of-range condition overloads the sensitive front ends of subsequent stages, which then take milliseconds to return from saturation (during which time signal-handling is lost). One solution is to limit the buffer amp output by clamping it to a low-impedance source through a series resistor and diode from the active line to each supply rail. This approach not only adds at least four discrete components, but also consumes considerable power. Even worse, there's a conflict: The buffer output driver needs to be low-impedance to drive the converter input capacitance, and the clamp must have low impedance to yield good clamping action. A low impedance driving a low impedance is a recipe for component failure.

A better solution is to use a clamping amplifier (**Fig 4**), such as Analog Devices' AD8036, Harris' HFA1135, or Comlinear's CLC501/502, which provide you with linear response within the normal input range along with "graceful" limiting at the extremes. This response is combined with fast recovery from clamp mode—typically, a few nanoseconds.

For optoelectronic applications, you can reduce component count, performance uncertainty, and cost by using an IC that has the photodiode and its required buffer amplifier in a single package. Burr-Brown's OPT211, for example, includes a photodiode and transimpedance op amp as a monolithic device in a clear eight-pin package, which also acts as an optical filter (**Fig 5**). The single-chip solution eliminates common problems of leakage current on the circuit board, noise pickup in critical paths, and gain peaking result-



A video sync stripper removes the timing signal, leaving the active part of the composite signal for further processing and digitizing.

MODELING IS NOT AS GLAMOROUS AS IT SOUNDS

Virtually every op-amp vendor provides Spice models, which are a very useful approximation of device performance. A good model attempts to resolve two contradictory impulses: It should use a minimum number of internal elements (especially nonlinear ones) to ease computing yet look like an accurate representation of the op amp as a "black box" (see **Ref 2**).

You should use these models as a necessary (but not entirely sufficient) step in the design process. Models cannot capture a device's every sensitivity to supply variations or temperature and load changes. Dynamics such as slew rate and overshoot are especially difficult to model. For current-feedback devices, where bandwidth is set by a feedback resistor at a given gain, it is very difficult for vendors to model performance at every closed-loop gain value.

Most available Spice models use typical rather than worst-case specs. Equally important, even a perfect model (if available) would not capture what's just as critical in high-performance analog design: your physical circuit that surrounds the part. Even a few picofarads of circuit-board capacitance affect peaking, for example, and conductive residues on the circuit provide a leakage path between IC pins. No op-amp model captures what your ground topology looks like.

All models are not created equal. The first op-amp Spice models, based on work by Boyle in 1974, used two poles, did not characterize supply or output current well, and referenced internal signals to ground. Although some models still use this approach, most vendors now have more sophisticated models, such as seven-pole configurations, which provide good trade-offs among complexity, convergence, and accuracy. In addition, vendors now pay extra attention to modeling the input and output stages of the op amp—which, after all, are the op amp's interface to your circuit.

Does this mean you shouldn't use models? Absolutely not! Use them for first-level assessments of your circuit, to about ±20% accuracy. At the same time, recognize that the model itself neither is perfect nor includes the subtleties of your design. Check with the vendor to understand which modeled specs are typical, which are worst-case, which are at room-temperature, and other similar limitations and simplifications.

Most vendors offer evaluation boards and suggested circuit-board layout drawings. Don't hesitate to use them. First, an evaluation board shows you what the part can do in an (assumed) optimal design. Second, the layout can serve as a reference design for your work, so you won't waste time discovering mistakes the application engineers have already made—and fixed. According to several vendors, the first question their engineers ask when a designer calls with a problem such as oscillation in high-frequency current-feedback circuits is, "Did you use the evaluation board design?"

ing from stray capacitance—attributes that models cannot easily accommodate (see **box**, "Modeling is not as glamorous as it sounds").

"Trimming" is a concept (and a chore) that has been associated with op amps since their earliest days. The most frequently performed trim lets you reduce or eliminate input-voltage offset, which shows up as a static output error. Trim's visible cost to you is one component (a trimming potentiometer), a larger op-amp package (those null pins), and some board space. Less tangible costs include additional production and test time, opportunity for misadjustment, and potential unreliability.

CURRENT VS VOLTAGE FEEDBACK

You must also consider op amps that use current feedback topology instead of the more familiar voltage feedback. Although there are many views about the virtues (and vices) of each, look closely at the benefits of each topology in your application.

Voltage feedback is what you probably learned in school; it's got those nice equations and looks simple to set up and probe. In current feedback, the error signal that feeds back to the input stage is, as the name states, a current; the input buffer's low output impedance allows large currents to flow through the negative input. This current is the slewing current, and slew rate is a function of the feedback resistor and change in output voltage. Therefore, the current-feedback amplifier has nearly constant output transition times, regardless of step size.

In performance, current feedback generally offers higher slew rate and lower power consumption than voltage feedback, and voltage feedback offers you flexibility in selecting a feedback resistor, two high-impedance inputs, and higher precision. With a current-feedback op amp, you set the bandwidth via an external resistor, which also allows you to make some design trade-offs among gain, bandwidth, and stability. You can use the same part in several places for quantity cost savings, using only as much bandwidth as needed to reduce noise energy.

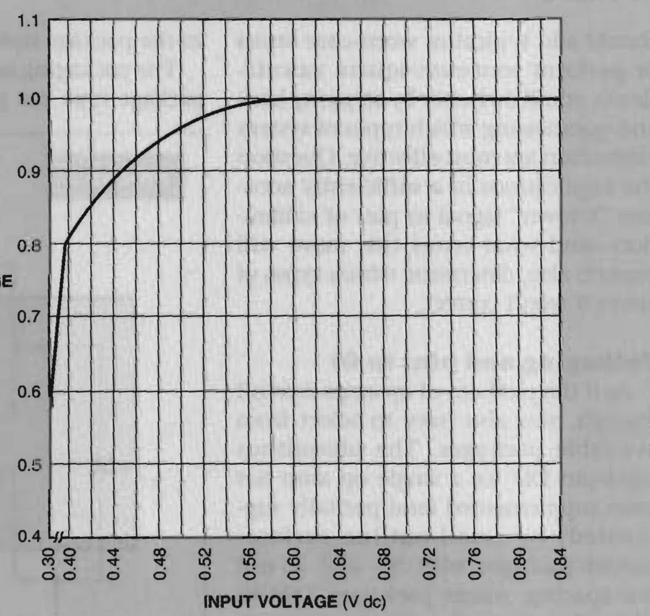
In general, current feedback is used only at higher frequencies, for applications such as professional video and high-performance instrumentation. Even at higher frequencies, some designers prefer to stay with voltage feedback, because they believe it's easier to use. Current feedback is less common in lower end consumer applications because it requires more design expertise.

Uniformly, op-amp vendors say that users don't want to do trims, and that they no longer have to in most cases. First, as a result of design and process improvements, offsets have gotten much smaller. Precision op amps now feature offsets below 100 μV. (Even better, the offset temperature coefficients—which cannot be trimmed easily—are also lower.) Also, trims are unnecessary in ac-coupled applications where the dc level is not relevant, such as in communications.

Even for dc applications, you can compensate for situations where a precision part isn't good enough by using software-driven calibration (in most cases). You'll probably need to do this calibration, anyway, to take care of various nontrimmable system errors.

Your ability to calibrate (and thus eliminate) errors, changes the traditional error-budget approach to analog-circuit design. Rather than work out elaborate spreadsheets to calculate the effect of various error sources (and thus avoid discussions over whether you

FIGURE 4



Clamping amplifiers provide a smooth transition into limiting mode at both extremes of the input-signal excursion, thus preventing saturation and overload (and time lost comes out of saturation) in subsequent stages; this feature is especially useful where the dynamics of the input are not well-behaved.

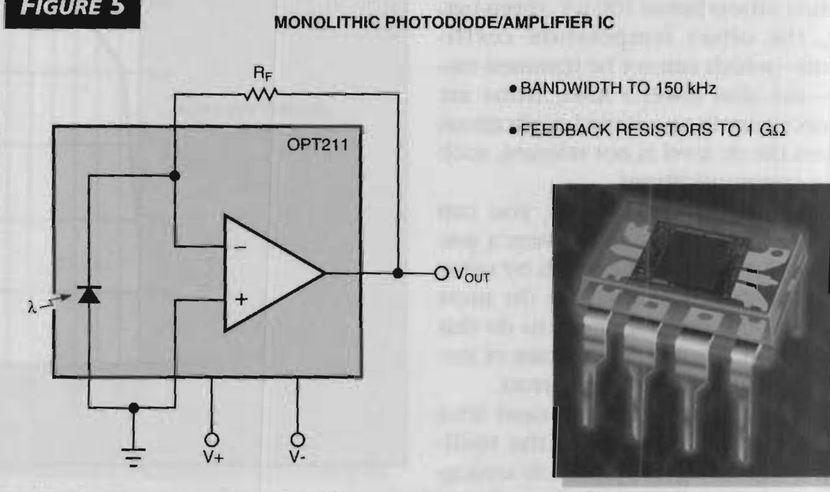
should add typical or worst-case errors or perform root-sum-square calculations), you'll do better by stepping back and questioning which types of system calibration are most effective. Question the implications of a sufficiently accurate "known" signal as part of calibration—and what errors this move will correct; also, determine which types of errors it won't correct.

Packaging and pins to fit

As if the plethora of op amps weren't enough, you also have to select from available packages. The ubiquitous eight-pin DIP for a single op amp has been supplemented (and partially supplanted) by small-outline surface-mount packages with 50- and 25-mil pin spacing, micro packages, TSSOPs (thin shrink small-outline packages), SOT-23 five-pin packages (3.05× 3×1.44 mm thick, which is approximately half the size of an SOIC), and more (Fig 6). Of course, the part with specs you need may not be available in the package style you want.

The packaging issue involves not just package type but pinouts. In the past, you could safely assume that virtually all op amps were at least available in that least-common-denominator eight-

FIGURE 5



Integrating a photodiode and its preamp into a single device, as in this Burr-Brown device, requires both appropriate electronic design and a clear package that actually functions as an optical bandpass filter.

pin DIP, so you could substitute and upgrade far along in your design—or even in production. Now, though, as op amps fragment for different applications, that's no longer true: A part intended for handheld phones has a package that's quite different from a part for driving cables in PCs.

Some parts are available only in dual or quad configurations because their single-channel versions would find few applications that are cost-effective. (In contrast, highest speed op amps, with bandwidths above several hundred megahertz, are often available in singles only, due to internal crosstalk problems.) Multichannel parts offer advantages besides saving board space and money. They often have quiescent currents only slightly greater than a single-channel device, but with better offset, temperature tracking of drift, matching, and other specs.

However, pinouts in multichannel configurations are much less standardized than the basic single-channel unit,

MANUFACTURERS OF OP AMPS

For free information on op amps such as those described in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Analog Devices Inc
Norwood, MA
(617) 937-1428
Circle No. 301

Burr-Brown Corp
Tucson, AZ
(800) 548-6132
Circle No. 302

Comlinear Corp
Fort Collins, CO
(800) 776-0500
Circle No. 303

Elantec Inc
Milpitas, CA
(800) 333-6314
Circle No. 304

Harris Semiconductor Corp
Melbourne, FL
(800) 442-7747
Circle No. 305

Linear Technology Corp
Milpitas, CA
(408) 432-1900
Circle No. 306

Maxim Integrated Products
Sunnyvale, CA
(408) 737-7600
Circle No. 307

Motorola Inc
Phoenix, AZ
(602) 413-3615
Circle No. 308

National Semiconductor Corp
Santa Clara, CA
(800) 272-9959
Circle No. 309

Texas Instruments Inc
Dallas, TX
(800) 477-8924, ext 3500
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Medium Interest 599
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OP AMPS

so substitutes are harder to find. You can even find high-performance eight-channel op-amp ICs, but check carefully before you design them in—they may be too much of a good thing in layout routing.

The old rule for op amps went something like this: You'd always need a second source—or at least an alternate source with comparable specs. Again, times have changed. For several reasons, designers no longer insist on backup sources for parts. The average product life cycle is much shorter than the lifetime of a good op amp. In addition, qualifying another source (you can't assume that other source will perform identically) is a task that many designers don't have time or expertise to do fully. Finally, if you're doing leading-edge design, you'll choose parts that give you the competitive edge (even if they are proprietary) and for which there may be nothing comparable in performance, cost, and functionality. Where the part will make the difference, carefully consider vendor competence and credibility. EDN

References

1. Rich, Allan, "Noise Calculations in Op Amp Circuits," LTC Design Note 15, September 1988.

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FIGURE 6

Package proliferation: The familiar eight-pin DIP for through-hole use has been been joined by the smaller, surface-mount eight-pin SOIC package. Many op amps for portable equipment are available in the even-smaller five-pin SOT23-5. (Photo courtesy National Semiconductor Corp)